Prepared By:

Municipality Of Brockton

Load Posting Evaluation
Greenock Structure No. 006

GMBP File: 216137-1

October 2020

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TABLE OF CONTENTS

1. INTRODUCTION **1**
1.1 Background 1
1.2 Purpose 1
1.3 Site Review 1
2. BRIDGE DESCRIPTION **2**
3. REHABILITATION HISTORY **2**
4. REVIEW METHODOLOGY **3**
5. BRIDGE REVIEW **3**
5.1 Abutments and Wingwalls 3
5.2 Stringers 3
5.3 Cross Beams 4
5.4 Wood Deck 4
5.5 Steel Truss Connections 4
5.6 Steel Truss Members 4
6. STRUCTURAL EVALUATION **5**
6.1 General 5
6.2 Evaluation Levels 5
6.3 Steel Properties 6
6.4 Evaluation Results 6
7. REHABILIATION COSTS **8**
8. RECOMMENDATIONS **9**

APPENDICES

APPENDIX A: PHOTOS
APPENDIX B: STRUCTURE LOCATION MAP
APPENDIX C: CHBDC FIGURE 14.8

LOAD POSTING EVALUATION

MUNICIPALITY OF BROCKTON

OCTOBER 2020

GMBP FILE: 216137-1

1. INTRODUCTION

1.1 Background

GM BluePlan Engineering Limited (GMBP) has been retained by the Municipality of Brockton (Municipality) to perform a load posting evaluation for Greenock Bridge Structure No. 006. The structure is located on Concession Road 8 over the Teeswater River. In 2020, GMBP completed the biennial bridge inspections for the two former townships, Brant and Greenock, which currently form part of the Municipality. The inspections involve attending each Municipality owned bridge and culvert, and assessing the current condition of the structure. As part of the inspection report, we recommended that Greenock Bridge Structure No. 006 be evaluated prior to the end of 2020 to determine the adequacy of the current load posting. The results of our load evaluation are detailed below.

It should be noted that GMBP completed the last load evaluation on this structure in 2016 based on our July 2016 site visit. The results of the previous load evaluation are included in Section 6.1.

1.2 Purpose

The purpose of the evaluation was to identify impairment of the structure due to deterioration, distress, or damage and perform calculations to evaluate a safe load capacity for the structure. The load evaluation has been carried out in accordance with CSA S6-19, Canadian Highway Bridge Design Code (CHBDC) and CSA S16-14, Structural Steel Design Standard.

1.3 Site Review

GMBP visited the site on May 1, 2020 to assess the overall condition of the structure as part of the biennial bridge inspections for the Municipality. Due to the condition of several structural elements, a site meeting was scheduled with Gregory Furtney on September 4, 2020 to discuss the current condition of the structure, as well as concerns regarding the adequacy of the current load posting. It was at this point that the Municipality requested the GMBP perform a load evaluation on the structure to determine if the current load posting needed to be reduced.

In accordance with the CHBDC, a site review was completed on September 22, 2020 by GMBP to accurately assess the condition of the structural members exhibiting advanced deterioration, damage or overstressing. Members were cleaned of debris and loose corrosion in localized areas to visually review and measure section loss or fatigue. A ladder was used to access elements on the underside of the bridge structure where the depth of the watercourse permitted.

Measurements of the various structural elements (stringers, cross beams, truss members, etc.) obtained from previous inspections were verified on site during our recent visit. Digital photographs were taken of deteriorated structural elements and have been included in Appendix A.

2. BRIDGE DESCRIPTION

Greenock Bridge No. 006 is a single lane, single span (35.0 m) structure located Lot 2, Concession 8/9. A map indicating the location of the structure is provided in Appendix ‘B’. The bridge is a steel through truss with an exposed laminated 2x6 timber deck. The deck is supported on steel stringers and cross beams. The steel trusses are constructed using back to back C180x18 channels as top chords and while the bottom chords are constructed of double steel plates ranging in size from 65 mm x 15 mm to 76 mm x 25 mm. The truss diagonal web members are comprised of 20 mm Ø rods and steel plates of varying sizes. The webs and chords of the trusses are connected using steel plates and 19 mm Ø rivets of varying quantity and spacing. The stringers and cross beams are steel W200x22 and S380x64 sections respectively.

Based on the construction method and deterioration of the bridge structure, it is estimated that the structure is approximately 100 years old.

Please note that all steel sizes have been estimated based on our field measurements and comparing these measurements with available steel sizes as described in the Handbook of Steel Construction (Eleventh Edition). Properties listed in this handbook were then used in our calculations.

3. REHABILITATION HISTORY

Please note that the rehabilitation history for the bridge structure detailed below is based on our limited records and only includes repairs completed in the last 36 years in which GMBP was involved (known as Gamsby and Mannerow Limited prior to 2014).

Prior to 1984, the south half of the west abutment was refaced with 300mm of concrete.

Between 1988 and 2002, the north half of the west abutment was refaced with 300mm of concrete. Load posting was updated from single load posting (8 tonnes) to triple load posting (7, 12, 19 tonnes).

In 2005, the existing timber plank deck was removed and replaced with a 2x6 laminated timber deck.

In 2008, a single cross beam located at the west end of the structure was replaced due to severe deterioration.

In 2012, the northwest bearing connection was replaced. The west portion of the north top chord and bottom chord were also replaced. It is believed that these repairs were required due to a failure of the bottom chord.

4. REVIEW METHODOLOGY

The procedures for completing a field review on an existing bridge are set out in the Canadian Highway Bridge Design Code (CHBDC). In general, the location and extent of concrete cracking, the areas of exposed or deteriorated reinforcement, and areas of loose, spalled or deteriorated concrete were noted. Steel elements including deck stringers, cross beams, truss top and bottom chords, and web members were closely examined for deterioration by corrosion and distress as a result of deterioration and loading.

5. BRIDGE REVIEW

5.1 Abutments and Wingwalls

The west abutment is in good to fair condition with localized stained cracks noted throughout. It should be noted that the abutment has been refaced with 300mm of concrete which could be concealing additional deterioration. The portions of the west wingwalls not refaced have severe deterioration and spalling.

The east abutment wall is in fair to poor condition with wide vertical cracks at each wingwall connection. It has not been determined if the cracks extend fully through the walls or not. The bottom southeast corner of the abutment has significant spalling and deterioration with exposed reinforcing. The bottom northeast corner has stained map cracking indicating that water may be penetrating the back of the abutment. The east wingwalls are in fair to poor condition with stained map cracking with efflorescence. The top of the east concrete footing is exposed exhibiting significant deterioration but has not been undermined at this point.

The bearing plates at each truss connection appear to be touching the front face of the ballast wall. A vertical crack on the ballast wall has been noted at each truss connection which could indicate that the truss is applying pressure to the ballast wall. At this point in time there does not appear to be any differential movement at any of the cracks.

Our review of the abutment bearing seats is limited due to the amount of vegetation and gravel covering the concrete. Medium to wide cracking was noted at each truss connection which could indicate the substructure is being overstressed by the truss connections. The northeast corner of the bearing seat is in poor condition with severe spalling and deterioration.

5.2 Stringers

The stringers are showing medium to severe corrosion throughout with more significant corrosion where the stringers are bearing on the abutments. In some cases, the corrosion has resulted in significant section loss and perforations through the webs of some of the stringers. Full height layers of corrosion have begun to flake off of the webs of the stringers. This was not observed during our 2016 review. The previous timber reinforcing installed between the flanges of the stringers is in poor condition and no longer providing support. The presence of the timber may have been detrimental, as it may have trapped water against the steel, accelerating the corrosion process.

5.3 Cross Beams

The cross beams are in fair to poor condition exhibiting severe corrosion and section loss in localized areas. In extreme cases, the top flange and bottom flange have approximately 80% and 50% section loss respectively., significantly more than observed in 2016. The vertical web of the cross beams has approximately 15% to 30% section loss with localized perforations near the bottom flange. Although the interior cross beams were not able to be closely inspected during the subject review, it appears that all the cross beams have experienced similar section loss with the exception of the western most cross beam, which was recently replaced in 2008.

5.4 Wood Deck

The wood deck is constructed using 2x6 laminated members. Based on our review, the deck appears to be in overall good condition with no members showing significant damage or deterioration.

5.5 Steel Truss Connections

Steel clip angles, bolts and rivets have moderate corrosion on them, and appear to be in overall good to fair condition except at the bearing connections.

The northeast, southeast and southwest bearing connections are in poor condition with severe corrosion and section loss. Perforations can be noted in connection plates and gussets which connect the top and bottom chord to the bearing plate. The northwest bearing connection is in good condition having been recently replaced in 2012. It has been recommended in previous bridge review reports that the tops of the abutments should be cleaned due to the large amounts of gravel and vegetation covering the bearing seat and truss connections. It is expected that the constant accumulation of gravel and vegetation growth on the bearing seats has allowed for moisture to be trapped against the concrete surface and truss connections, thus accelerating the deterioration of these components.

The rivets at the northeast and southeast bearing connections are in poor condition with severe corrosion and section loss. While trying to clean the loose corrosion off of the steel members over the bearing plates, the interior end of several rivets fell off.

5.6 Steel Truss Members

The bottom and top chord are exhibiting significant corrosion and section loss (30% to 75%) at the northeast and southeast bearing connections. The remaining portions of the bottom and top chord, as well as all webs, are showing signs of minor deterioration and section loss (10% to 15%). Several of the vertical webs within the truss and portions of the bottom chord are permanently deformed. It should be noted that connections at the top of the truss were visually reviewed from the deck surface only.

6. STRUCTURAL EVALUATION

6.1 General

Currently, Greenock Structure No. 006 has a triple load posting of 7, 12 and 19 tonnes. The last load evaluation completed on the bridge was in 2016 which determined that the triple load posting should be revised to 6, 12 and 19 tonnes (not completed).

The live load capacity of the existing bridge superstructure was investigated in accordance in accordance with Section 14 – Evaluation of the CHBDC. Evaluation levels 1, 2 and 3 (for Ontario Trucks) were considered in detail.

Our analysis was carried out by modelling all elements of the bridge superstructure in S-Frame Design Software. The structure's geometry, material properties, section properties or member sizes, computed loads and load factors for desired limit state design were input into the design software. The model allows for the axial loads from each of the above noted evaluation levels to be moved across the structure with the worst-case scenario for each element being considered as the governing element. Final factored forces (Moments, Shears, Axial Loads, etc.) including the effects of dynamic load allowance (DLA) and distribution of live loads were obtained at the critical locations for various components such as stringers, cross beams, etc.

The cross beams were considered as simply supported beams with appropriate wheel loads applied through the stringers. The wheel loads were applied along various locations across the span of the stringers to simulate a truck moving over the bridge.

The stringers were considered as continuous span beams with the truck wheels situated so as to produce the highest stresses in the member. The composite action of the wooden deck was neglected and the deck was considered to evenly distribute the axle and lane loads evenly to each stringer.

It should be noted that a detailed structural evaluation was not carried out on the concrete substructure. There are numerous wide cracks in the substructure which have been noted for an extended period of time (the crack in the abutment was noted in a 2002 inspection report). In our opinion, the abutments, wingwalls and footings will not be the governing elements for the safe load carrying capacity of the structure.

6.2 Evaluation Levels

The CHBDC evaluation procedure considers three broad categories of vehicles:

Level 1 .... Trains consisting of more than one trailer (CL1-625-ONT)
Level 2 .... Vehicle combinations with one trailer or semi-trailer (CL2-625-ONT)
Level 3 .... Single unit vehicles (CL3-625-ONT)

Each category considers different vehicle weights distributed over different axle configurations. These weights and axle configurations are specified in the code.

6.3 Steel Properties

The steel members listed below are the major structural components of the bridge truss. The following table summarizes the steel properties of these members as listed in the Handbook of Steel Construction.

	Stringers	Cross Beams	Bottom Chords x 2 (Middle)	Bottom Chords x 2 (Ends)	Top Chords (Channels with Plate)
Depth (mm)	206	381	76	65	178
Flange Width (mm)	102	140	N/A	N/A	55
Web Thickness (mm)	6.2	10.4	20	15	8.0
Flange Thickness (mm)	8.0	15.8	N/A	N/A	9.3
Area (mm^2)	2860	8150	3040	1950	6420
Section Modulus (x 10^3 mm^3)	194	980	38.50	21.10	282
Plastic Modulus (x 10^3 mm^3)	222	1140	57.80	31.70	N/A
Moment of Inertia (x 10^6 mm^4)	20.0	187	1.46	0.67	84.60

As the bridge is believed to have been constructed between 1905 and 1932, a yield strength (Fy) of 210 MPa was used, based on CHBDC Table 14.1. A tensile strength (Fu) of 380 MPa was used in accordance with CSA S16-09, Handbook of Steel Construction.

6.4 Evaluation Results

Prior to determining an adequate load posting, the evaluation relates the condition of each structural member to the evaluation levels detailed above. The CHBDC provides an equation for determining the live load capacity factor, F, as shown below:

$$F = \frac{UR_r - \Sigma\alpha_D D - \Sigma\alpha_A A}{\alpha_L L(1+I)}$$

Each structural element receives an ‘F’ value for each evaluation level with full vehicle loading, as well as reduced vehicle loading with additional lane loading. The structural element with the lowest ‘F’ values dictates the load posting results. To determine whether a load posting is required, the following rules are considered:

- If the ‘F’ value calculated for a CL1-625-ONT loading is equal to or greater than 1.0, a load posting is not required for the bridge.
- If the ‘F’ value calculated for a CL1-625-ONT loading is less than 1.0 but greater than 0.3, a triple load posting is required for the bridge.
- If the ‘F’ value calculated for a CL1-625-ONT loading is less than 0.3 but greater than 0.3 for the CL3-625-ONT loading, a single load posting is required for the bridge.
- If the ‘F’ value calculated for a CL3-625-ONT loading is less than 0.3, consideration should be given to closing the bridge.

It should be noted that the ‘F’ value is utilized to determine a Posting Factor, P, on Figure 14.8 in the CHBDC (see Appendix C). The posting factor is multiplied with the gross weight of the vehicle for each evaluation level to determine the load posting limit. Therefore, the minimum load posting for each vehicle with a minimum ‘F’ value of 0.3 is the following:

- CL1-625-ONT 0.028 (P) x 625KN = 17.5 tonnes
- CL2-625-ONT 0.020 (P) x 505KN = 10.1 tonnes
- CL3-625-ONT 0.011 (P) x 330KN = 3.60 tonnes

Based on the results of our load evaluation, the following members have been deemed critically deficient based on the ‘F’ values calculated (since these values are less than 0.3):

Structural Element	CL1-625-ONT	CL2-625-ONT	CL3-625-ONT	CHBDC Recommendation
Cross Beams	0.254	0.254	0.254	Close Structure
Bottom Chord	0.116	0.125	0.149	Close Structure
Gusset Plate at Bearing	0.149	0.168	0.216	Close Structure

It should be noted that our 2020 analysis has considered MTO Technical Report Document No. SRR-88-04 – Bridge Testing – A Surprise Every Time (1988). This document provides recommendations for evaluating pin-connected steel truss bridges (i.e. Greenock Structure No. 006) with double member tension chords (bottom chords). Based on several tests, it was determined that a bottom chord with two members does not distribute the load evenly between both members. In fact, the test results determined that only one member has a tendency to take all the load. This uneven loading pattern was not considered in our 2016 load evaluation as the existence of the MTO document was unknown, but has been considered in our 2020 load evaluation.

Based on the evaluation results detailed in the above table, the bridge code recommends consideration to be given to closing the bridge structure. At the current ‘F’ values listed and based on linear interpolation of Figure 14.8 (Appendix C), the bridge should have a single load posting of 1.8 tonnes. Considering that a majority of vehicles utilizing the bridge would weigh more than this load limit (especially winter maintenance vehicles), we recommend that the structure be closed to all vehicle loading.

The Municipality has requested that we also consider the possibility of leaving the bridge open for pedestrian traffic only. The bridge code requires that a live load of 3.80 KPa (CHBDC 3.8.9) be considered for the subject bridge if it is utilized as a pedestrian bridge. Based on our analysis, the current condition of the bridge has capacity to support approximately 0.90 KPa (less than 25% of the bridge code requirements). It should also be noted that the existing barrier system on the bridge does not meet the code requirements for pedestrian traffic. Therefore, we recommend that the bridge structure also be closed to all pedestrian loading.

The bridge structure has been inspected by GMBP since 1977. Based on our records, the east bearing connections have been recommended for replacement since 2012 due to significant deterioration. Based on the results of the load evaluation and our on-site review, the east bearing connections have reached the end of their service-life. Due to the significant temporary shoring required to replace these connections, the approaching winter months and the impacts that COVID-19 has had on recent tender results, we expect that repairs to the structure could not be completed before the end of 2020 without significant repair costs. A preliminary cost estimate has been provided below to inform the Municipality on the potential cost of these repairs.

7. REHABILIATION COSTS

Based on our understanding of the project, we anticipate that the following repairs would need to be completed to keep the bridge open beyond 2020:

- Replacement of the NE, SE and SW bearing connections.
- Replacement of the NE and SE bottom chords.
- Replacement of 3 to 4 cross beams.
- Concrete repairs to the east bearing seat.

These repairs would require significant temporary shoring to support the truss as components are removed and replaced. We estimate that the total rehabilitation cost for these repairs would be in range of **$150,000 to $200,000 (excluding HST).** It should be noted that this opinion of cost has been prepared with limited design details and is based on probable conditions affecting the project. Factors such as contractor availability, schedule of work and COVID-19 restrictions can have a significant affect on the cost of these repairs, especially if this work is expected to be completed before the end of 2020 and deemed as emergency work. If the above repairs are completed, we expect that the structure could remain open for an additional 5 to 10 years at most. Due to the condition of the substructure and the remaining steel truss members, we would still recommend that the bridge be posted with a single load posting even if the repairs are completed. The load posting would be determined when the detail design of the repairs are completed.

8. RECOMMENDATIONS

Based on the current condition of the structure and the results of the load evaluation, we recommend that the Municipality take the following steps:

- Close the structure to all vehicle and pedestrian traffic prior to the beginning of Winter 2020. Barricades should be installed at each end of the bridge along with signage indicating the closure.
- The Municipality should begin budgeting for the permanent removal or replacement of the structure within 1-5 years. It is our opinion that attempting to perform any repairs to the existing structure at this point would only provide a minimal extension in the service life of the bridge at a significant cost to the Municipality.
- Initiate a Municipal Class Environmental Assessment (MCEA) on the structure to determine the impacts to the surrounding environment, including local agricultural and residential communities, if the structure is permanently removed or replaced.
- Increase the frequency of inspections for the structure to every 6 months to monitor the deterioration of the deficient members until a decision regarding the future of the structure can be determined by the Municipality. If the bridge is closed and winter maintenance is not completed on bridge, significant snow loading could accumulate. Increasing the frequency of the bridge inspections will allow the Municipality to monitor the bridge more closely and if required, implement temporary repairs if an element on the bridge appears to be failing.

Should you have any questions about this report, or if you require input on rehabilitation or replacement options, please feel free to contact the undersigned.

All of which is respectfully submitted,

GM BLUEPLAN ENGINEERING LIMITED
Per:

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APPENDIX A:
PHOTOS

Photo 1 - View of structure from west (May 1, 2020).

Photo 2 - View of south truss (May 1, 2020)

Photo 3 - View of soffit looking east (May 1, 2020).

Photo 4 - View of southeast bearing connection (September 22, 2020).

Photo 5 - Severe corrosion and section loss at southeast bearing connection (September 22, 2020).

Photo 6 - Approximately 75% section loss at east end of south bottom chord (September 22, 2020).

Photo 7– Severe corrosion and section loss of gusset plate at southeast bearing connection (September 22, 2020).

Photo 8 - View of northeast bearing connection (September 22, 2020).

Photo 9- Severe corrosion and section loss at northeast bearing connection (September 22, 2020).

Photo 10 - Severe corrosion and section loss of gusset plate at northeast bearing connection (September 22, 2020).

Photo 11 - Severe corrosion, section loss and perforations at east cross beam (September 22, 2020).

Photo 12 - Approximately 80% section loss at top flange of cross beam (September 22, 2020).

Photo 13 - Approximately 50% section loss at bottom flange of cross beam (September 22, 2020).

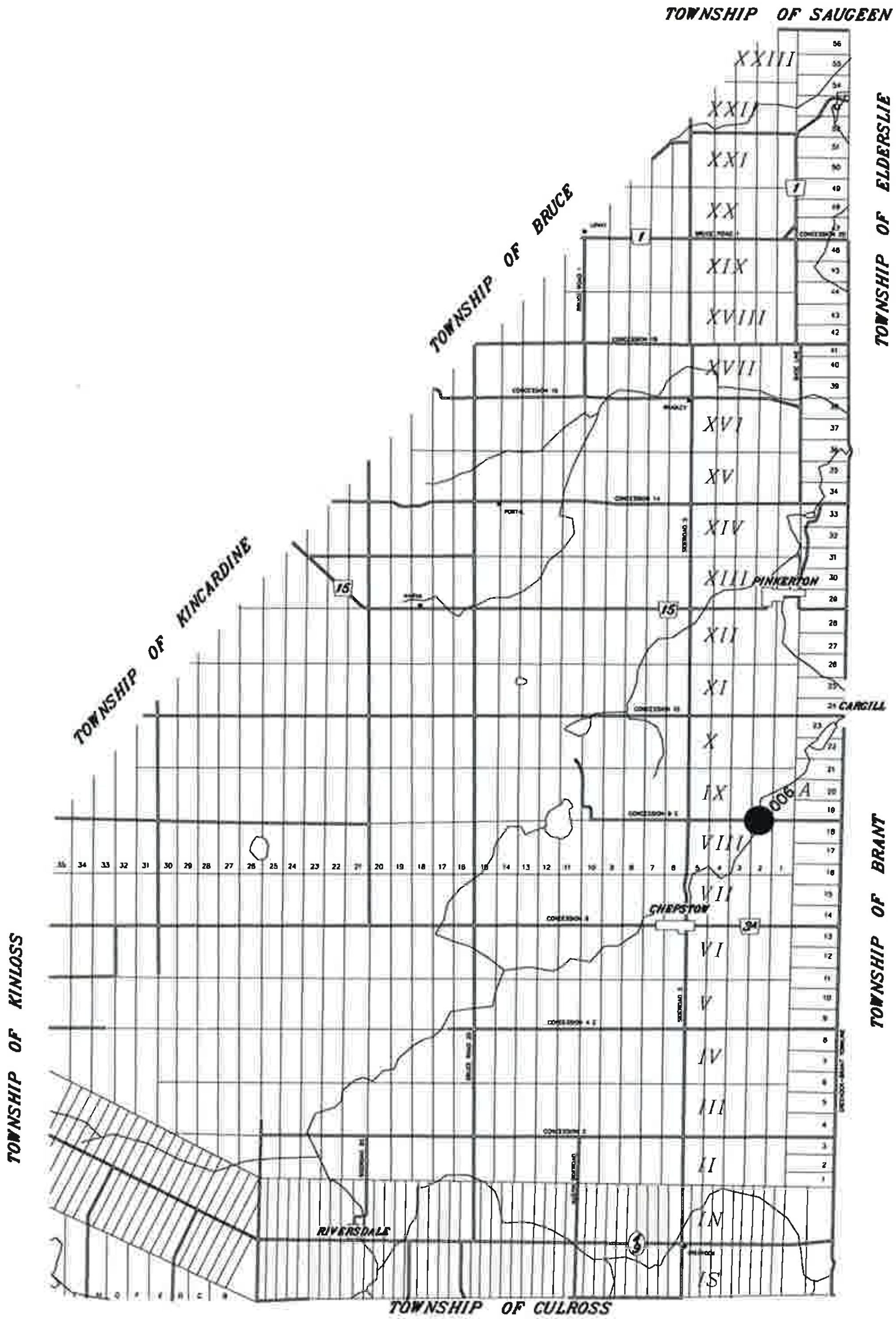
Photo 14 - Large perforation (350mm x 50mm) at north end of cross beam near mid span (September 22, 2020).

Photo 15 - Approximately 30% section loss throughout stringer supports (September 22, 2020).

Photo 16 - Significant concrete deterioration and spalling noted adjacent to northeast bearing connection (September 22, 2020).

APPENDIX B:
STRUCTURE LOCATION MAP

216137-1
Municipality
of Brockton



SITE LOCATION MAP

SCALE: N.T.S.

BRIDGE LOAD EVALUATION

GREENOCK
BRIDGE No. 006
MUNICIPALITY OF
BROCKTON

Figure No. 1

GM BluePlan ENGINEERING

GMBP FILE:216137-1 Br No.6 Site Location Map-C.dwg LAYOUT:1
LAST SAVED: 1/13/2017 11:28:20 AM PLOTTED: 1/13/2017 11:38:00 AM

APPENDIX C:
CHBDC FIGURE 14.8

Subject to Approval, a concrete bridge with multiple load paths need not be posted if it has been carrying normal traffic without signs of excessive material cracking, deformation, or degradation. Such a bridge shall be inspected at intervals recommended by the evaluator.

14.17.2 Calculation of posting loads

When Evaluation Levels 1, 2, and 3 are used as a basis for posting, the smallest value of *F* from Clause 14.15 or 14.16 shall be calculated and applied as follows:

(a) when $F \geq 1.0$ for Evaluation Level 1, posting shall not be required;

(b) when $1.0 > F \geq 0.3$ for Evaluation Level 1, triple posting shall be required, with the posting loads for each evaluation level being obtained from Figure 14.8 for the appropriate value of *F* for each evaluation level;

(c) when $F < 0.3$ for Evaluation Level 1 and $F \geq 0.3$ for Evaluation Level 3, single posting corresponding to Evaluation Level 3 shall be required, with the posting load being obtained from Figure 14.8 for Evaluation Level 3 only; and

(d) when $F < 0.3$ for Evaluation Level 3, consideration shall be given to closing the bridge.

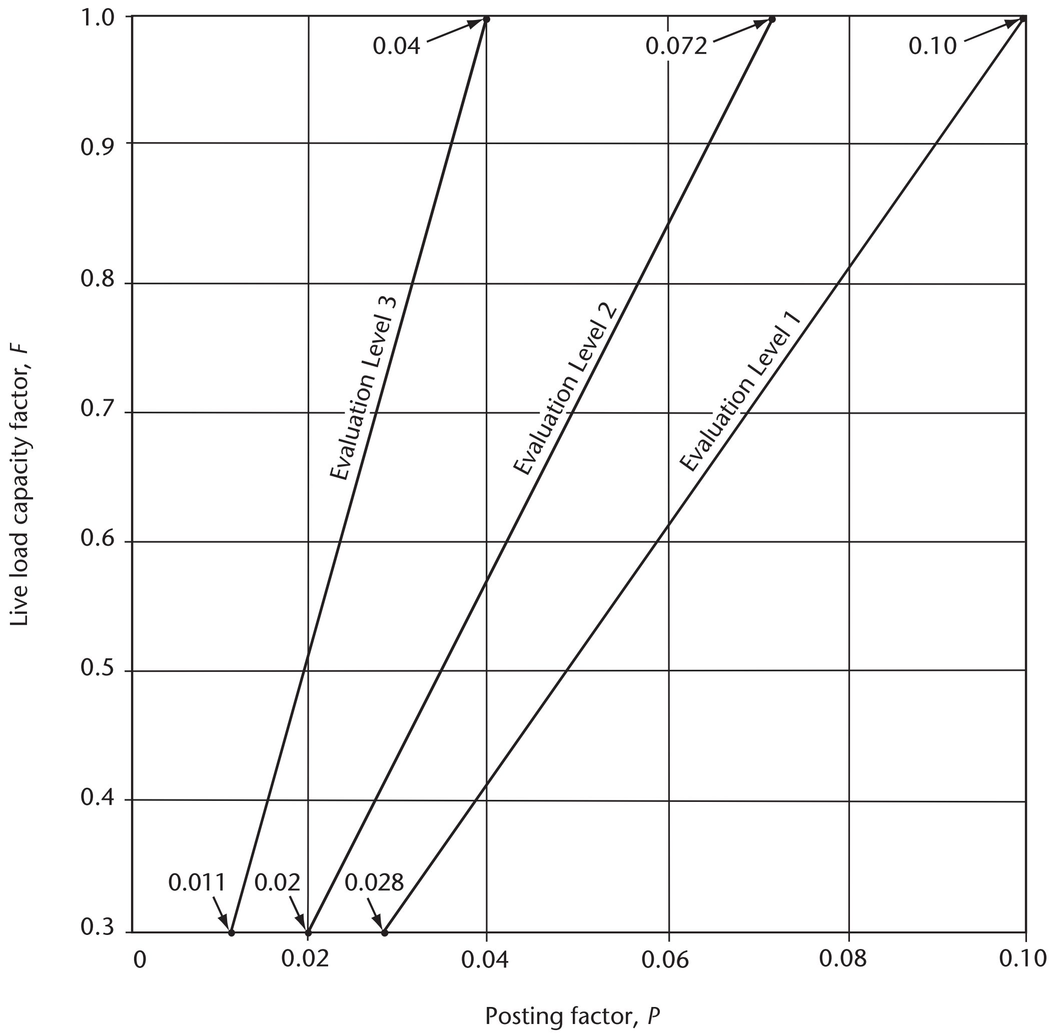


Figure 14.8
Posting loads for gross vehicle weight
(See Clauses 14.17.2 and 14.17.3.1.)